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Girvin

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[45] **Mar. 25, 1975**

[54] **SUPPORT AND FOCUS STRUCTURE FOR PHOTOMULTIPLIER**

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[52] **U.S. Cl.** **313/95,** 313/105, 313/253
[51] **Int. Cl.** **H01j 39/02,** H01j 39/14
[58] **Field of Search** 313/95, 252, 253, 99

[56] **References Cited**

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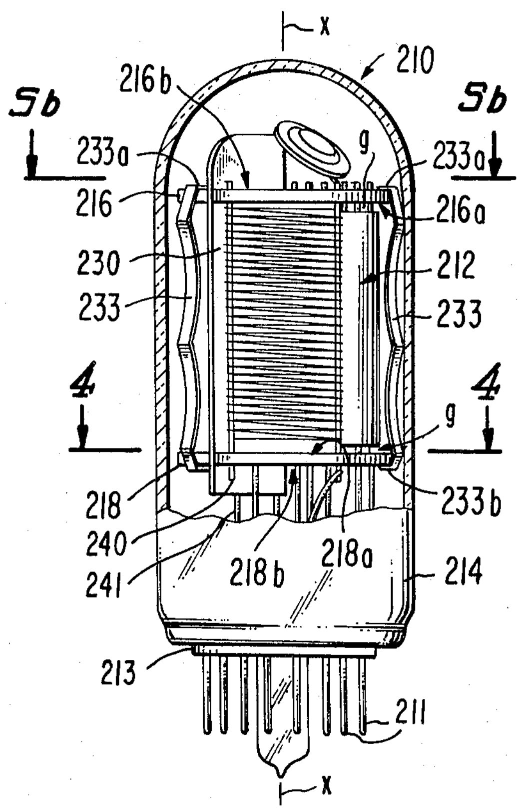
[57] **ABSTRACT**

A mounting means is provided for substantially electrically isolating an electrode assembly of a photomultiplier from the inner surface wall of a glass envelope. The electrode assembly also includes an electrode focussing means for substantially preventing divergent electrons from impinging on electrode support spacers. The combination substantially eliminates the operational electrical instability known as hysteresis.

3 Claims, 6 Drawing Figures



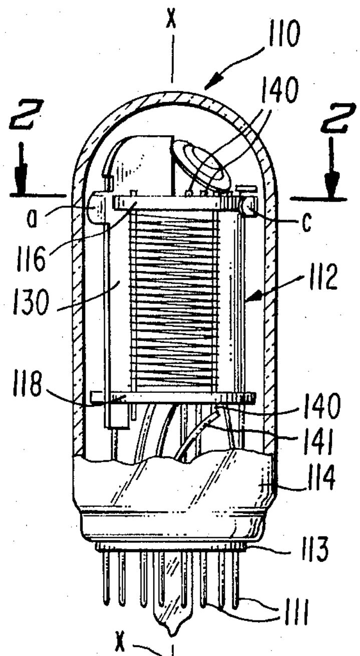
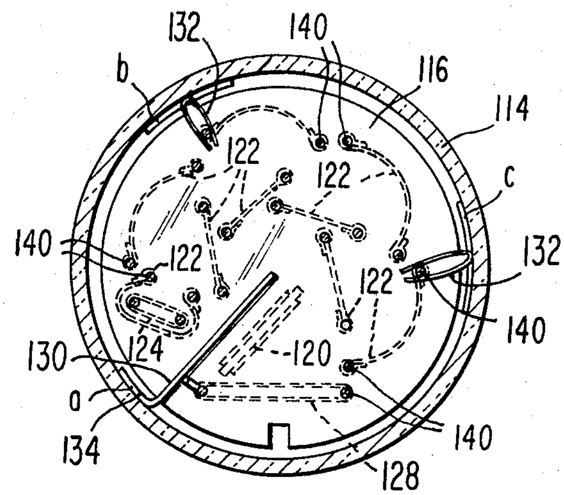


FIG. 1. PRIOR ART

FIG. 2. PRIOR ART



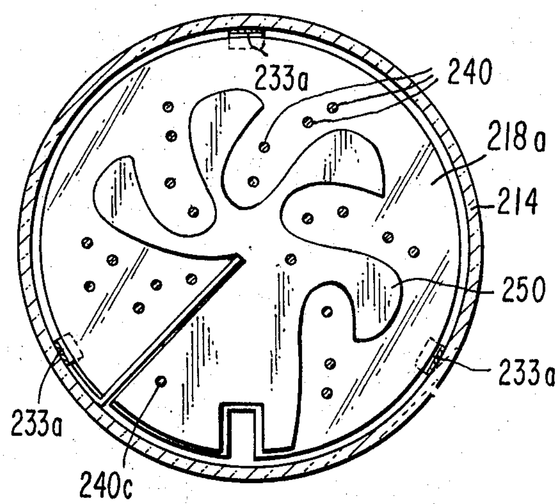


FIG. 4.

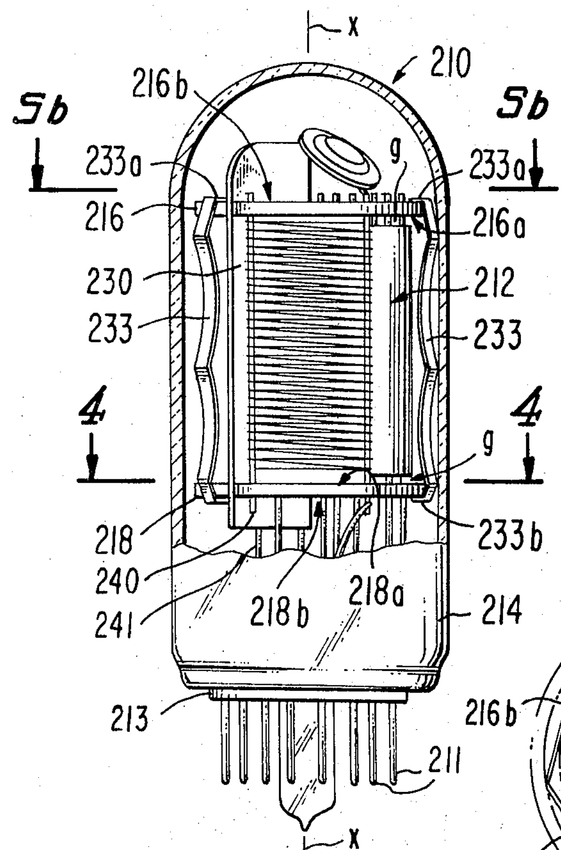


FIG. 3.

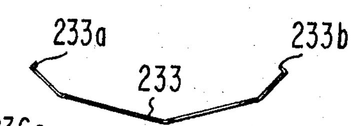


FIG. 5.

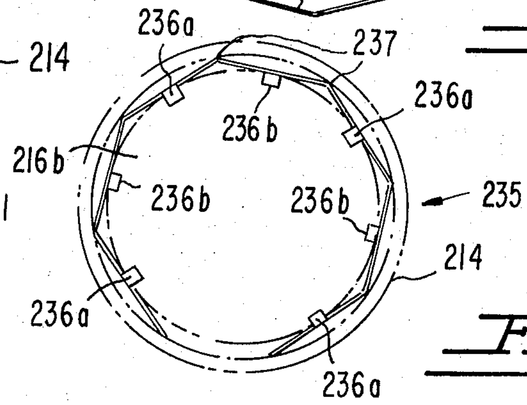


FIG. 6.

SUPPORT AND FOCUS STRUCTURE FOR PHOTOMULTIPLIER

BACKGROUND OF THE INVENTION

The present invention relates to a photomultiplier tubes, and more particularly to the assembly of photomultipliers having improved operating stability.

Photomultiplier tubes, in general, include: a photocathode, for generating electrons in response to light focused to impinge therein; an electron multiplier, for amplifying or multiplying the electron current generated by the photocathode, and an anode, for collecting the multiplied electrons. The usual electron multiplier comprises a series of secondary emitting dynodes and is interposed between the photocathode and the anode. The photocathode, dynodes, and anode together generally comprise the electrodes of the device.

In the construction of one type of photomultiplier tube, commonly known as the "side-on type," the electrodes of the device are connected longitudinally in a "circular cage" arrangement between two support spacers and are supported therebetween by wire mounting posts extending through retaining holes in each support member. This integral electrode assembly is mounted within an evacuated glass envelope. Various support members have been devised to rigidly or resiliently retain the electrode assembly within the glass envelope in addition to the partial support provided generally by the lead wire connections to the pins of the device. These support members have generally consisted of a plurality of individual metal spring leaves, which are, for example, secured by welding, to the wire electrode supports. Another type of prior art support member has consisted of individual spring leaf brackets which commonly extend parallel to the longitudinally extending electrodes and clamp over an insulated region of a support spacer at each end of the electrode assembly. In general, the various support members have been utilized without consideration of the electrically adverse "hysteresis" effects hereinafter described.

Photomultiplier tubes of the side-on type are used, for example, in photometry applications for the detection of intermittent light signal inputs of varying signal intensity. In general, photomultipliers used in such applications have exhibited a temporary instability in anode current and a change in anode sensitivity for several seconds after the application of a light input signal and the application of appropriate operating voltages to electrodes of the device. Sensitivity of the device may overshoot or undershoot a few percent before reaching the stable value. This instability, sometimes called hysteresis because of cyclic behavior is believed to be caused by electrons striking and charging the electrode support spacers and the glass envelope, thereby changing the electron optics within the tube. The time required to reach a stable value is believed to be related to the resistance of the support spacers, its surface capacitance and the photomultiplier current.

Several constructional modifications of photomultiplier tubes have been attempted in search of a device substantially free of the instability previously described (i.e., a "hysteresis free" device), with varying degrees of success. One such approach consists of coating the electrode support spacers with a conductive material and connecting this coating to cathode potential. In the

operation of such a device, the conductor region acts in the manner of a focussing electrode preventing divergent electroms from impinging on the respective support spacers. Yet another approach, consists of providing a hard glass envelope comprising, for example, a type 9741 glass in lieu of the less expensive and more easily assembled lime glass envelope ordinarilly employed in the assembly of such prior art devices. These and other approaches to the problem have been shown to be inadequate in that they are ineffective, expensive and/or impractical.

SUMMARY OF THE INVENTION

A photomultiplier tube includes an electrode assembly having a series of electrodes longitudinally extending between insulated support spacers within a glass envelope. An isolating mounting means is provided for retaining the electrodes in substantially fixed, mechanically aligned relation with the inner wall surface of the envelope and for substantially avoiding electrical charge communication between the inner wall surface of the envelope and the electrodes. An electrode focussing means is provided for substantially preventing divergent electrons from impinging on the support spacers.

BRIEF DESCRIPTION OF THE DRAWINGS

FIg. **1** is a cut-away perspective view of an assembled photomultiplier tube made in accordance with the prior art.

FIG. **2** is a cross-sectional view of the tube depicted in FIG. **1.**

FIG. **3** is a cut-away perspective view of one example of an assembled photomultiplier tube made in accordance with the invention.

FIG. **4** is a cross-sectional view of the tube depicted in FIG. **3.**

FIG. **5** is a diagrammatic depiction of the cross-sectional contour of the resilient mounting means shown in FIG. **3.**

FIG. **6** is a diagrammatic depiction of the cross-sectional contour of an alternative resilient mounting means for the tube depicted in FIG. **3.**

BRIEF DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIGS. **1-2** and FIGS. **3-4** there is shown, respectively, a prior art photomultiplier **110,** and a photomultiplier **210** made in accordance with the invention. Numerical designations of corresponding portions of each device include a variation of the first digit to clearly designate the intended device. The disclosure hereinafter presented is intended to apply equally to such corresponding portions of either device having otherwise similar numerical designation numbers.

Referring more specifically to FIG. **1,** the prior art photomultiplier **110** includes an electrode assembly **112** resiliently mounted within an evacuated cylindrical glass bottle or envelope **114.** The electrodes of the photomultiplier **110** are mounted longitudinally (i.e., parallel to axis X-X) in circular cage fashion (i.e., along the cross-sectional plane perpendicular to axis X—X depicted in FIG. **2**) between two parallel support plates or spacers **116** and **118.** The spacers **116** and **118** may be composed of any of the well known ceramic or glass insulating materials generally employed in the fabrication of parts for electron discharge devices. One ceramic material is, for example, disclosed in U.S. Pat. No. 3,037,874 issued to L.P. Garvey on June 5, 1962.

Referring to FIG. 2, the electrodes of the photomultiplier **110** includes: photocathode **120**, dynodes **122**, anode **124**, light permeable wire grid **128**, and the electrode shielding plate **130**.

The electrode assembly **112** is resiliently secured within the glass envelope **114** in a manner well-known in the art by the electrode assembly mounting means comprising a plurality of resilient metal spring clips **132** (FIG. 2) or spring leaf **134** which are disposed symmetrically around the circumference of the spacer **116**. The metal clips **132** are individually welded or otherwise securred to electrode wire mounting posts **140** which protrude through and are rigidly mounted to the respective spacers **116** and **118**. The wire mounting posts **140** provide a means of rigidly mounting the electrodes (by welding or other suitable securring means known in the art) of the device and facilitate the wire interconnections by the wires **141** to the lead pins **111**. The spring leaf **134** consists of a turned-in or inwardly extending depression of the plate **130**.

In the assembly of the photomultiplier **110**, the upper portion of the integrally assembled electrode assembly comprising spacers **116–118** together with the electrode assembly mounting means, electrodes **120–130**, glass stem **113** and interconnection lead wires **141** is forcefully inserted into sliding abutting engagement with the inner wall of the envelope **114**. The resilient spring clips **132** and spring leaf **134** are constrained during insertion and provide a firm but resilient mounting means for the electrode assembly subsequent to the sealing closure and evacuation of the envelope at the stem **113** in a manner well known in the art.

Persons skilled in the art of photomultipliers have, in general considered the selection of an appropriate mounting means for the electrode assembly to be independent of the hysteresis effect associated with electrical operation of the device. For this reason, prior art photomultipliers, such as depicted in FIGS. **1–2**, have either intentionally electrically interconnected one or more of the metal clips **132** or spring leaves **134**, or mechanical equivalents thereof, to one or more of the electrode potentials for ease of manufacture, or have incidently permitted one or more of the electrodes to make electrical contact with the inner wall surface of the envelope. As hereinafter clarified, I have discovered the selection of an appropriate electrically isolating mounting means to be a critical factor in reducing the hysteresis effects previously described.

Referring to FIGS. **3** and **5**, one embodiment of Applicant's invention is shown in which the mounting means consists of a plurality of metallic spring leaf brackets **233** disposed symmetrically about the spacers **216** and **218**, wherein the electrode assembly **212** is electrically isolated from and maintained in substantially fixed mechanically aligned relation to the inner cylindrical wall surface of the envelope **214** to a degree sufficient to substantially avoid electrical charge communication between the inner cylindrical wall of envelope **114** and respective electrodes.

Spring leaf brackets **233** (FIG. **5**) are fabricated in a manner well-known in the art to provide a firm but resilient support for the electrode assembly **212**. Turned-in depressions or tabular extensions **233*a*** and **233*b*** of brackets **233** are resiliently attached or secured to insulated regions (non-coated regions of the ceramic

through which no electrode wire mounting posts **240** protrude) of the outer surfaces **216*b*** and **218*b*** of the ceramic spacers **216** and **218**. Brackets **233** are retained in fixed aligned relation with respect to the spacers **216, 218** by the elastic force of the individual metal brackets, **233**, once constrained to straddle or clamp the ceramic spacers **216** and **218** in the manner depicted in FIG. **3**.

Referring to FIG. **4**, a conductive region **250** is provided on each of the respective inner surfaces **216**a and **218**a of ceramic spacers **216** and **218**. The conductive region **250** preferably consist of a metallization, such as molybdenum, aluminum or other conductive metallic coating, which may be respectively applied to the ceramic spacers, for example, by silk screening, evaporation-masking or other techniques, well known in the art. Unlike the prior art embodiment described with regard to FIG. **1**, the electrode assembly **212** may include a gap or separation "*g*" (FIG. **3**) between the electrodes and the spacer surfaces **216*a*** and **218*a***, selected to avoid electrical contact between individual electrodes and conductive regions **250**.

The conductive regions **250** are electrically connected to photocathode potential by means of the wire post **240*c***, or other suitable electrical connecting means. In an operative device, wherein suitable operating voltages are applied to lead pins **211**, the conductive region **250** acts as a focussing electrode for preventing divergent electrons from striking the spacers **216, 218**.

The conductive region **250** should extend over the inner regions of ceramic spacers **216** and **218** upon which the electrons, which are divergent from their desired electron trajectories between electrodes **220–230**, would otherwise most likely impinge. This surface region of each spacer generally overlies and is most proximate to the interelectrode electron trajectories.

Broadly, my invention consists of interposing, in a photomultiplier, (1) a mounting means for an electrode assembly which includes high electrical resistance (i.e., electrical charge isolation) between the inner wall surface of a glass envelope and the electrodes of the device, in combination with (2) focussing means for substantially preventing divergent electrons from impinging on the electrode support spacers. Surprisingly, I have found that photomultipliers employing this novel combination have unique advantages unexplained by the expected individual contributions of either element (1) or (2) individually.

An operative example of the novel photomultiplier depicted in FIGS. **3–5** was constructed having a cylindrical glass envelope approximately 140 mm. long, 25 mm. in diameter, and comprised of a type 008 lime glass. The metallization region **250** consisted of a molybdenum material applied to insolating ceramic spacers **216, 218** by silk-screening techniques suitable for electron discharge tube applications, and wherein the brackets **233** were fabricated of a "Inconel" material approximately .24 mm. thick, **30** mm. long and 3 mm. wide. The stem **213** was fabricated of a Na—Ca—Si—PbO_2 type glass suitable for electron discharge devices.

Surprisingly, evaluations of the electrical performance characteristics of the novel device, above described, indicate that the undesirable hysteresis effects previously described have been substantially eliminated. Additionally, I believe this unexpected result was occasioned by the provision in a photomultiplier of an electrically isolated mounting means for the electrode assembly for substantially avoiding electrical charge communication between the inner wall surface of the envelope and the electrodes, in combination with an electrode focussing means for substantially preventing divergent electrons from impinging on the support spacers **116** and **118.** The resilient mounting means described herein is designed specifically to provide the additional non-mechanical function of electrically isolating the glass envelope from direct electrical connection with the electrodes of the device, thereby substantially avoiding electrical charge communication between the inner wall of the envelope and one or more of the electrodes.

From the foregoing characterization of my invention, it is apparent that various alternative but equivalent mechanical arrangements of the electrode assembly mounting means may be provided. For example, clips such as **132** (depicted in FIGS. **1–2**) may be fabricated of suitable insulating materials if those materials possess the requisite degree of flexibility, resiliency, or other mechanical characteristics required for the application.

Referring to FIG. **6** there is depicted an alternative example of the mounting means for the electrode assembly **212** comprising a single resilient member **235.** The member **235** may comprise a single continuous band of 3 mm. wide, 0.25 mm, thick Inconel metal; however, other metal materials may be similarly fabricated and used to advantage which have similar resilient properties. The member **235** is fabricated in the shape of a ring to include multiple inward facing flat surfaces, each including attaching tabs **236***a* or **236***b* which protrude inwardly from opposite sides of the metal band. In assembly, the ring member **235** is preferably snaped around the circumference of the spacer **216.** Thereafter the member **235** is retained integrally with the spacer **216** by the elasticity of the metal band and by the retaining action of the tabs **236***a* and **236***b* which respectively overlap opposite surfaces of the spacer **216.** The photomultiplier is thereafter assembled in the conventional manner. In this alternative example, the electrode assembly is resiliently retained in substantially fixed aligned relation to the cylindrical inner wall surface of the envelope **214** by the constrained mechanically elastic action of the protruding angular contact regions **237** of the member **235** which abutt with and are constrained by the inner wall surface of envelope **214.**

GENERAL CONSIDERATIONS

An alternative but equivalent electrode may be provided in lieu of the conductive coating **250,** comprising, for example, an independent and separate metallic electrode interposed parallel to the spacer surface **116***a* on **118***a* within the region *g* (FIG. **3**). Also a, non-cathode potential could be applied to region **250,** or to such other electrode configuration, to advantage so

long as the requisite degree of focussing of divergent electrons is achieved. Appropriate electrical isolation is provided between the electrode wire mounting posts **240** and the conductive region **250** on the surfaces **216***a* and **218***a*. Preferably this isolation is accomplished by means of non-metallized, non-conductive insulating surface regions on the inner surfaces **216***a* or **218***a*, however other methods of electrical isolation may be employed. Preferably, the conductive region **250** comprises a continuous surface region of metallization; however a plurality of individual surface regions of metallization may be utilized with equal advantage when suitable interconnected to an appropriate source of operating potential.

I claim:

1. A photomultiplier comprising, in combination:

a. a light transmissive evacuated glass envelope having an inner and outer wall surface,

b. a stem portion sealed to one end of the glass envelope, the stem portion including a plurality of lead-in pins extending within said envelope,

c. an electrode assembly, within the envelope, including a plurality of spaced-apart electrodes including: a photocathode, at least one dynode, and an anode; said electrodes being secured longitudinally, at their opposing ends, between two substantially parallel support plates of insulating material; various ones of the electrodes being interconnected by lead wires to respective ones of said lead-in pins,

d. a plurality of spring members each having a plurality of resilient portions fixably constrained between the inner wall surface of said glass envelope and portions of the electrode assembly which are electrically isolated from various ones of the electrodes, to retain the electrode assembly in substantially fixed mechanically aligned relation with the inner wall surface of said envelope, and to substantially electrically isolate the electrodes of the electrode assembly in spaced-apart relation from the inner wall surface of said envelope, and

e. a plurality of electron focusing electrodes, interposed between said support plates and ends of the electrodes of said assembly securred to said support plate; said focusing electrodes comprising conductive metallization regions on said support plates, overlying interelectrode regions between respective ones of the electrodes, through which electrons may be accelerated, whereby electrons may be substantially prevented from impinging upon said support plates.

2. A photomultiplier in accordance with claim **1** wherein each focusing electrode comprises a single conductive metallization region on each of said support spacers.

3. A photomultiplier tube in accordance with claim **1**, wherein said spring members each comprise a resilient spring member mechanically securred to the periphery of at least one of said support plates.

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